BEST AVAILABLE COPY

(12) UK Patent Application (19) GB (11) 2 221 810 (13) A

(43) Date of A publication 14.02.1990

(21) Application No 8915631.9

(22) Date of filing 07.07.1989

(30) Priority data
(31) 8816277 (32) 08.07.1988 (33) GB

(51) INT CL[4]
H04B 9/00

(52) UK CL (Edition J)
H4B BH

(56) Documents cited
GB 2141258 A

(58) Field of search
UK CL (Edition J) H4B BA BH
INT CL[4] H04B 9/00

(71) Applicant
University College London

(Incorporated in the United Kingdom)

Gower Street, London, WC1E 6BT, United Kingdom

(72) Inventor
Jean-Claude Adam Chaimowicz

(74) Agent and/or Address for Service
Elkington & Fife
Beacon House, 113 Kingsway, London, WC2B 6PP,
United Kingdom

(54) Optical transmission arrangement

(57) An optical transmission arrangement comprises a transmitter (T1) at a first location for transmitting to a receiver (R1) at a second location. The first transmitter (T1) has a plurality of selectively activatable optical emitters (1.1 to 5.5) which are so arranged that light from each emitter leaves the transmitter at a different angle. In one embodiment the receiver (R1) detects the angle at which the light arrives and causes an error signal to be transmitted back to the first location to control which of the emitters is activated. Alternatively, a second transmitter (T2) transmits an independent pilot signal to a second receiver (R2) at the first location which detects the angle at which it arrives, and the detected angle is used to control which of the emitters of the first transmitter (T1) is activated.

The transmitter (Figs 1-3) comprises an array of fibres (1.1-5.1) associated with respective lasers (or a single laser coupled to the fibres) and embedded in a plate (P) aligned with a plano-convex lens (L) causing the light from each fibre to emerge at a unique angle.

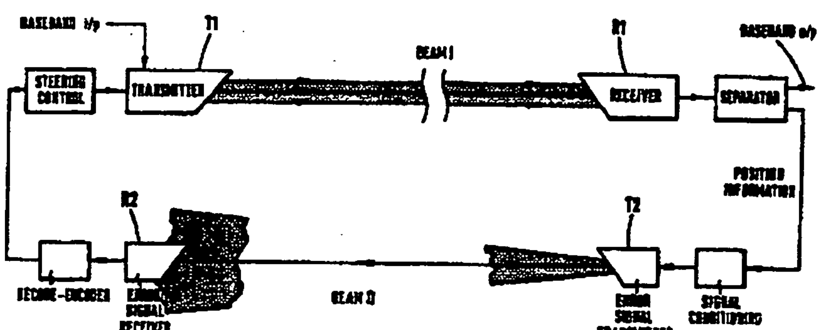


Fig.4

GB 2 221 810 A

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

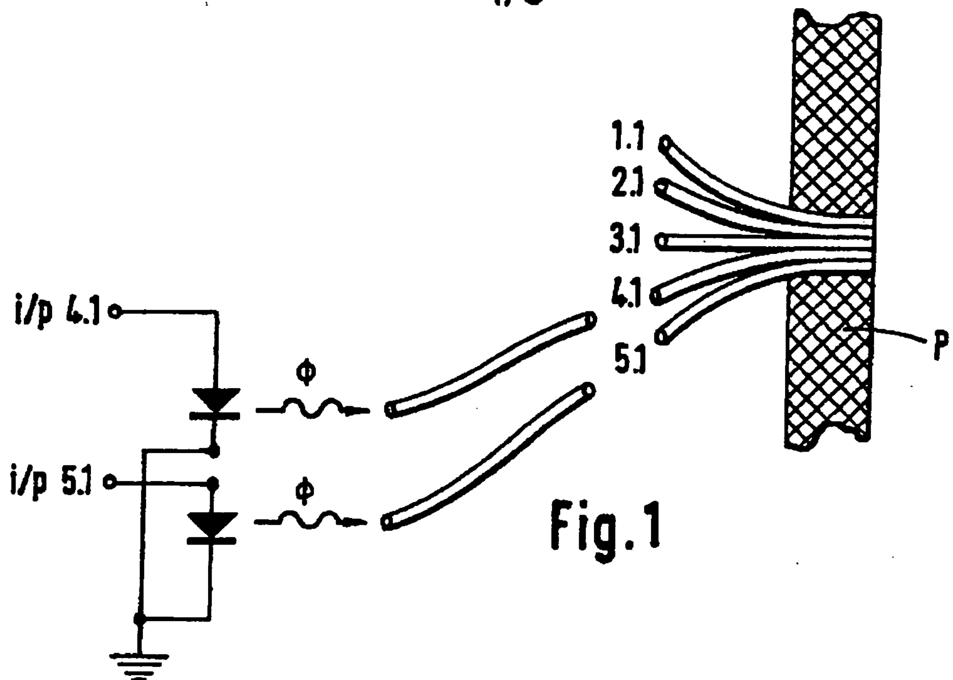


Fig.1

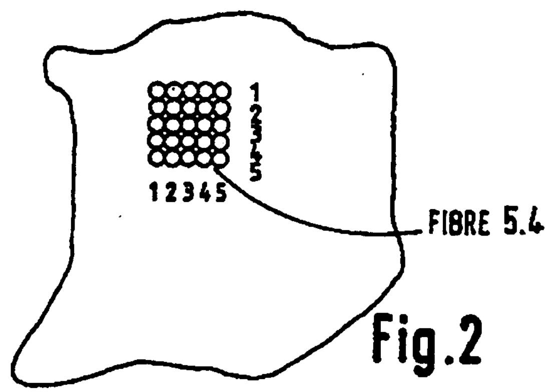


Fig.2

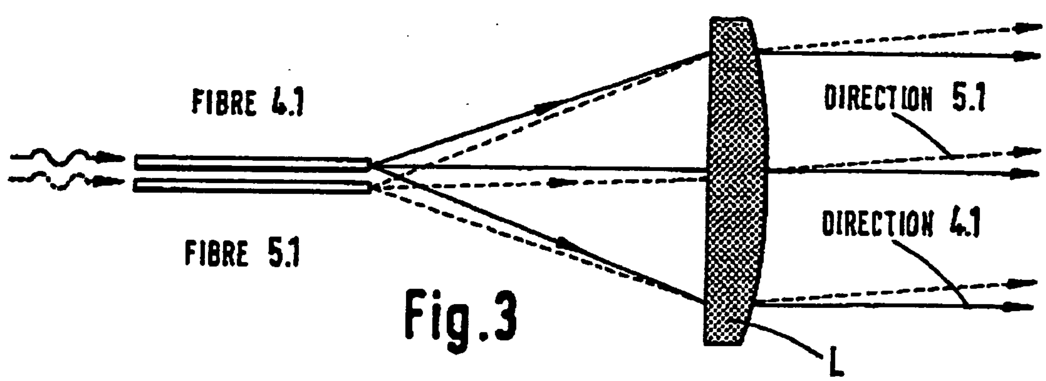


Fig.3

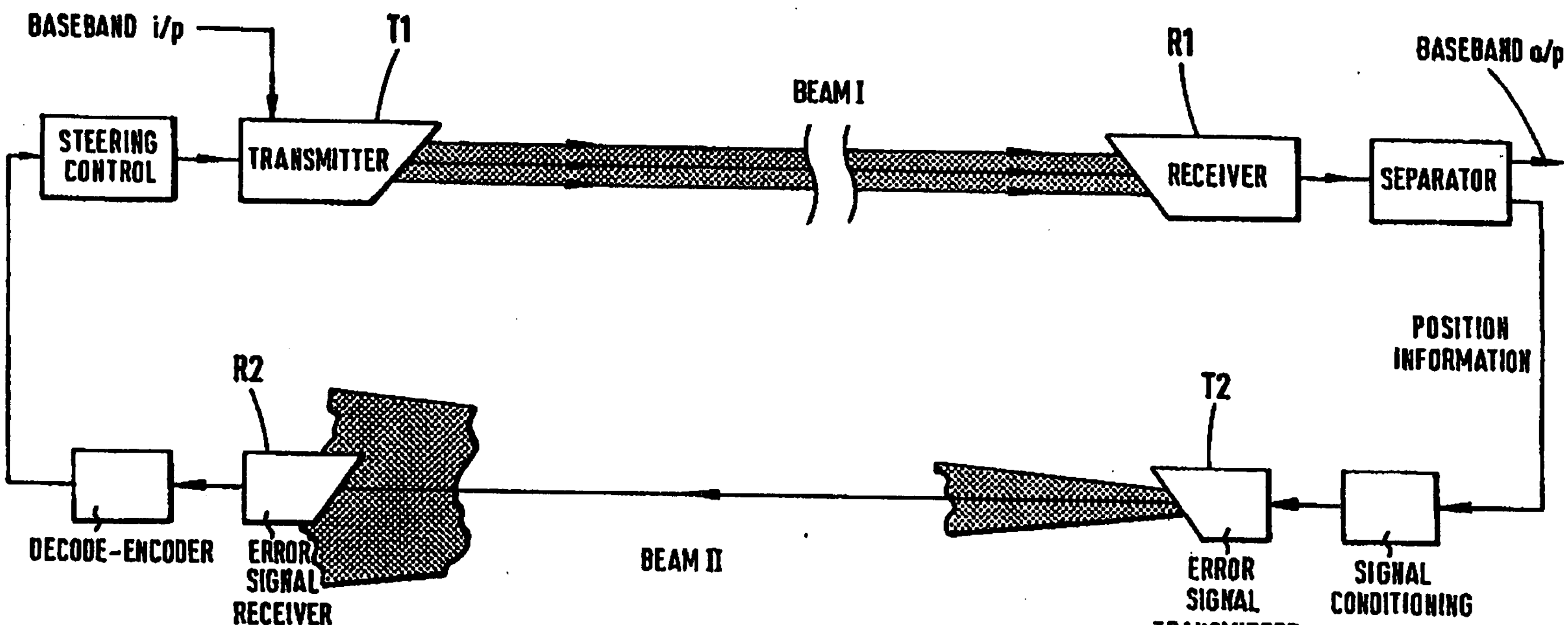
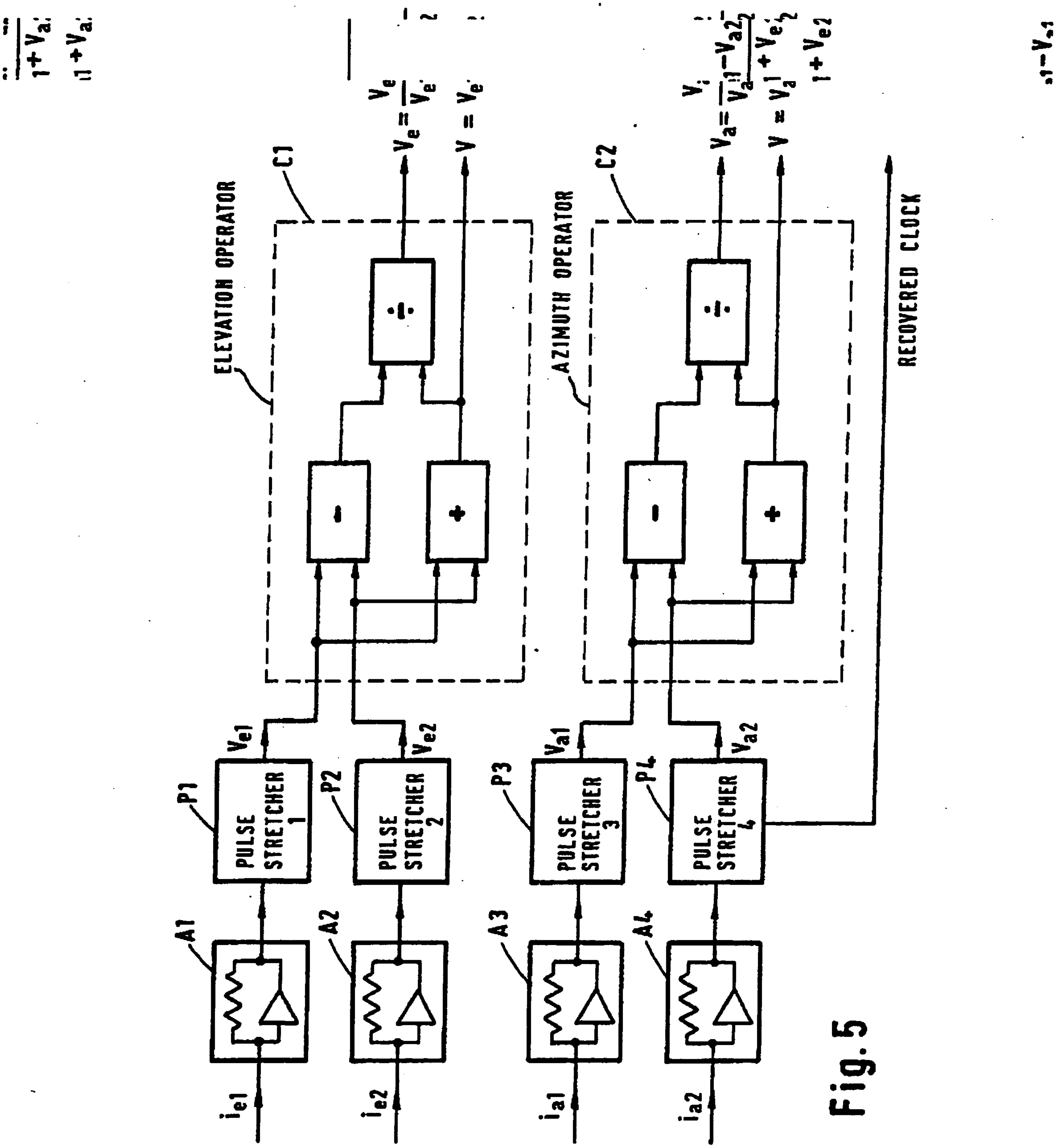

BASEBAND i/p
T1
STEERING CONTROL
TRANSMITTER
BEAM I
R1
RECEIVER
SEPARATOR
BASEBAND o/p
POSITION INFORMATION
R2
T2
DECODE-ENCODER
ERROR SIGNAL RECEIVER
BEAM II
ERROR SIGNAL TRANSMITTER
SIGNAL CONDITIONING

Fig. 4



ELEVATION OPERATOR
C1
AZIMUTH OPERATOR
C2
RECOVERED CLOCK
A1
A2
A3
A4
P1
P2
P3
P4
PULSE STRETCHER 1
PULSE STRETCHER 2
PULSE STRETCHER 3
PULSE STRETCHER 4
i_{e1}
i_{e2}
i_{a1}
i_{a2}
V_{e1}
V_{e2}
V_{a1}
V_{a2}

Fig.5

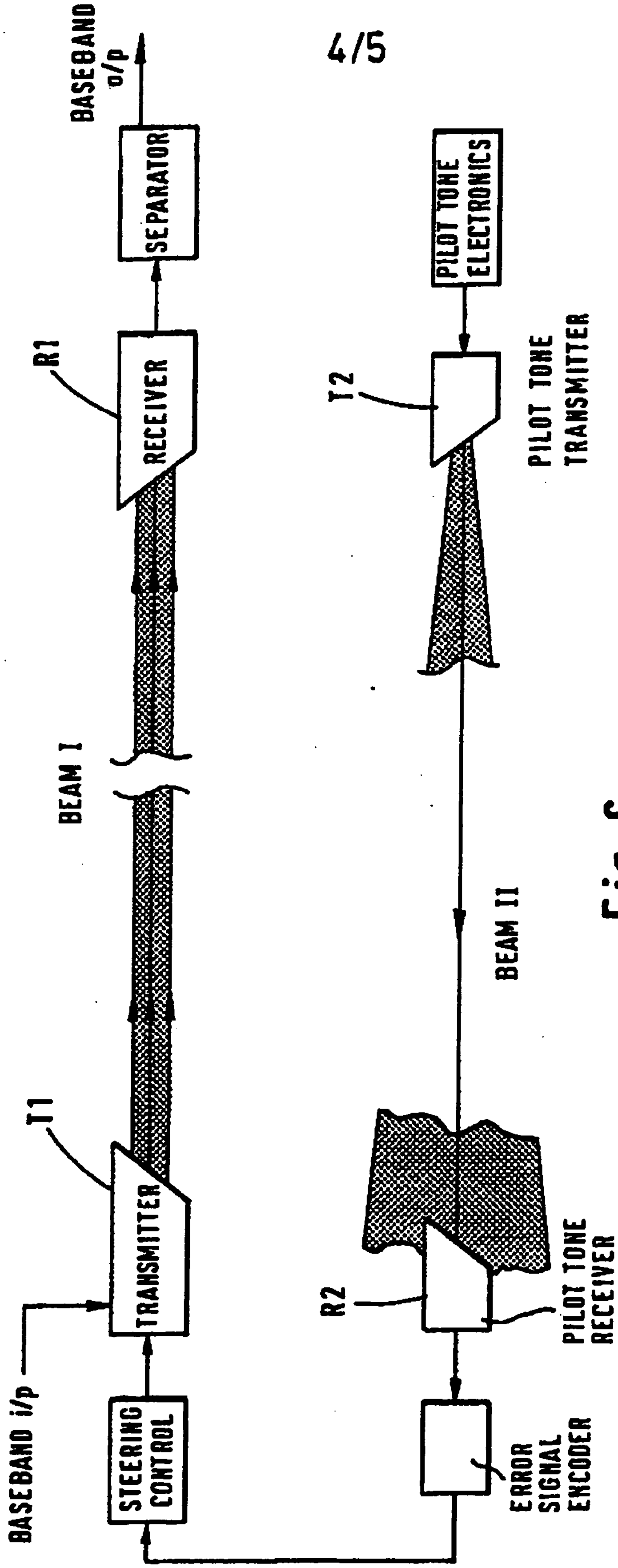

BASEBAND o/p
SEPARATOR
R1
RECEIVER
PILOT TONE ELECTRONICS
T2
PILOT TONE TRANSMITTER
BEAM I
BEAM II
T1
TRANSMITTER
BASEBAND i/p
STEERING CONTROL
R2
PILOT TONE RECEIVER
ERROR SIGNAL ENCODER

Fig. 6

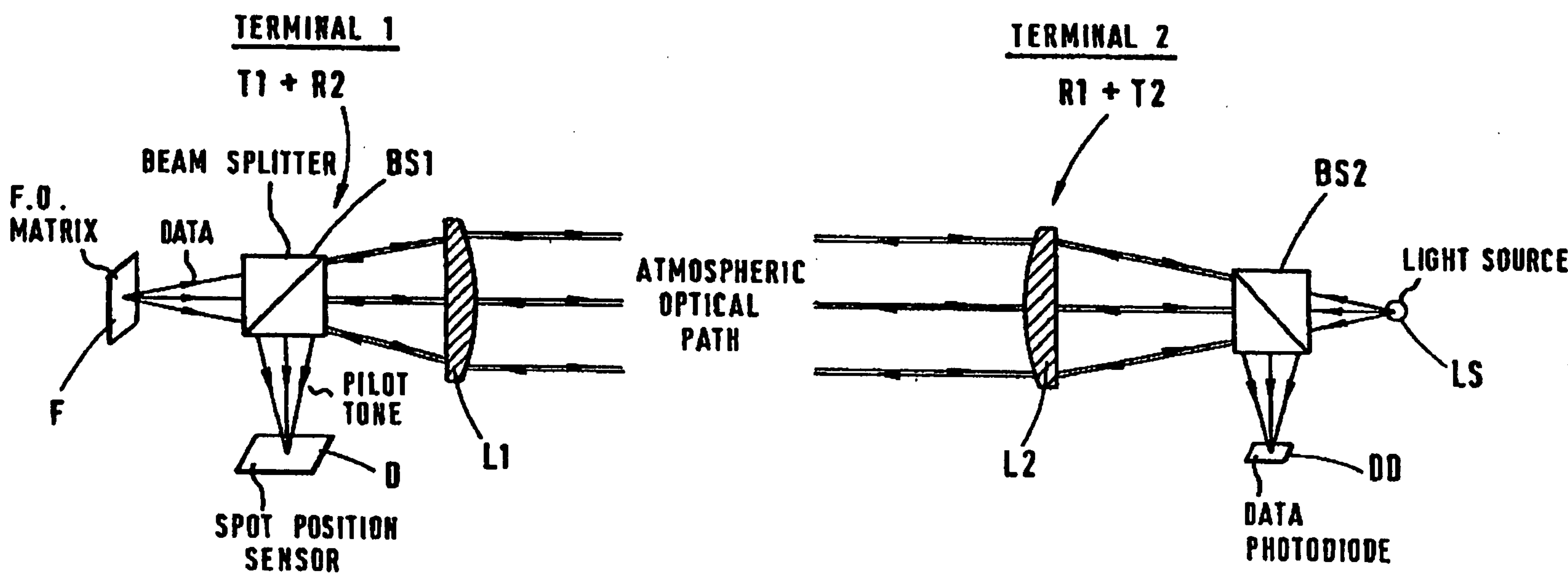

TERMINAL 1
T1 + R2
BEAM SPLITTER
BS1
F.O. MATRIX
DATA
F
PILOT TONE
D
SPOT POSITION SENSOR
L1
ATMOSPHERIC OPTICAL PATH
TERMINAL 2
R1 + T2
BS2
LIGHT SOURCE
LS
L2
DD
DATA PHOTODIODE

Fig. 7

2221810

OPTICAL TRANSMISSION ARRANGEMENT

This invention relates to an optical transmission arrangement.

In recent years optical arrangements have been increasingly used for the transmission of data, and interest has largely centred on the use of optical signals guided by means of optical waveguides. However, there are circumstances in which it is either impossible or inconvenient to guide optical transmissions in this way, and for such circumstances a non-guided arrangement is required.

However, the use of non-guided optical transmissions encounters problems in maintaining alignment between the optical transmitter and the optical receiver. Firstly, where the medium through which transmission is taking place is anything other than free space, for example where it is the atmosphere, variation in the medium with time produces variation in the optical path. Thus, in typical atmospheric conditions refractive bending takes place which deflects the path of the optical beam during the course of its travel by an extent which varies with time as the atmospheric conditions vary. This has compelled designers hitherto to use relatively large

beam spreads. This invention makes it possible to use narrower beams and is thereby conducive to a greater penetrating power in turbid atmospheres, giving greater ranges. Secondly, misalignment between the transmitter and receiver may be produced by movement of the transmitter and/or the receiver. The problem is particularly acute where the transmitter or receiver is mounted on a structure such as a ship which necessarily does not remain completely stationary.

Known non-guided optical transmission arrangements may use a mechanical tracking arrangement for maintaining alignment between transmitter and receiver. However, such mechanical arrangements are bulky and therefore slow to respond to changes which may be required. So called adaptive systems based on displaceable or bending mirrors suffer from similar predicaments. It is an object of the present invention to provide an optical transmission arrangement by means of which the alignment between the transmitter and receiver can be maintained in a fashion superior to that provided by mechanical arrangements.

According to the present invention there is provided an optical transmission arrangement comprising a transmitter located at a first location and having a plurality of optical emitters which are selectively activatable, the emitters so arranged that light from each emitter leaves the transmitter at a different

angle; receiver means for receiving the light from the transmitter and detecting the angle at which it arrives; and means for selectively activating a given emitter in dependence on the angle detected by the receiver.

Two embodiments are described in detail below. In each embodiment there is a second transmitter and a second receiver arranged to receive a signal from the second transmitter, the second transmitter being in the vicinity of the first receiver and the second receiver being in the vicinity of the first transmitter.

In one emboidment of the invention the said receiver means is constituted by the first receiver which both receives the light from the first tansmitter and detects directly the angle at which it arrives. The means for selectively activating a given emitter comprises the second transmitter, which transmits an error signal to the second receiver. The error signal controls which emitter in the first transmitter is activated.

In the second embodiment, the said receiver means comprises both the first and second receivers. The first receiver receives light from the transmitter but does not detect the angle at which it arrives. The second transmitter transmits lto the second receiver which detects the angle at which that light arrives. Because a ray passing along an optical path between two

points A and B follows the same path whether it travels from A to B or from B to A (at least in the case of media which are not very severely scattering), the angle detected by the second receiver represents the angle at which the light from the first tansmitter reaches the first receiver, and hence constitutes an indirect detection thereof.

The invention further provides an optical transmission arrangement comprising a transmitter having a fixed optical system and a plurality of optical emitters spaced from one another and selectively and individually activatable, the disposition of the emitters with respect to the fixed optical system being such that light from each emitter leaves the transmitter at a different angle.

The invention is further described below with reference to the accompanying diagrammatic drawings, in which:

Figure 1 is a view, partly in section, of the emitters with which the transmitter is provided;

Figure 2 is a front elevation of the emitters of Figure 1;

Figure 3 shows generally the transmitter;

Figure 4 is a diagram illustrating a first embodiment of the complete optical arrangement;

Figure 5 shows diagrammatically the electronics of a receiver R1 used in the arrangement of Figure 4;

Figure 6 is a diagram illustrating a second embodiment of the complete optical arrangement; and

Figure 7 shows how, in the embodiment of Figure 6, the first transmitter and second receiver can be combined, and how the second transmitter and first receiver can be combined.

As can be seen in Figures 1 to 3, the transmitter comprises a plurality of optical fibres, the ends of which are mounted in a plate P to form an array which can be seen most clearly in Figure 2. By way of example an array in the form of a rectangular grid is shown, but other arrays could be used instead. Figure 1 shows the five fibres which make up column 1 of the array, namely 1.1, 2.1, 3.1, 4.1 and 5.1. As is explained below, the use of different fibres within a column provides variation in the elevation of the emitted beam, and the use of different fibres within a row provides variation in the azimuth of the beam. In transmission through the atmosphere from a receiver which is truly stationary to a receiver which is also truly stationary the main cause of misalignment between the transmitter and receiver is an atmospheric effect which causes the beam to be bent upwardly or downwardly to a varying extent. Under such circumstances it may be sufficient to provide correction only for misalignment in elevation, in which case only a single column of fibres may be used.

Each of the optical fibres is pigtailed to a suitable source of optical radiation, for example a GaAs laser. Two such lasers are represented diagrammatically in Figure 1, connected respectively to fibres 4.1 and 5.1. It will be understood, however, that each fibre in the array has its own source of optical radiation. Figure 1 also shows two signal inputs for the fibres 4.1 and 5.1 respectively. If a signal is applied to the input for the fibre 4.1 radiation will be emitted from the corresponding laser, will pass down the fibre 4.1 and will be emitted from the end thereof located in the plate P. Similarly, a signal applied to the input for fibre 5.1 will cause light to be emitted from the end of that fibre, and so also for all the other fibres in the array. The output ends of the fibres constitute, in this embodiment, the emitter means called for by the invention.

An alternative to the arrangement just described is to have a single laser for feeding all the optical fibres, and controlled signal routing exploiting known routing techniques.

As can be seen in Figure 3, those ends of the fibres which are located in the plate P, i.e. the ends which form the array shown in Figure 2, are located in the focal plane of an optical system which, in this case, is a plano-convex lens L. It will be

understood, however, that many other optical systems could be used in place of the lens L, for example other lens arrangements or mirrors. Because the ends of the fibres are spaced apart in the array light emerging from the end of a given fibre emerges from the lens L in a direction unique to the fibre concerned. Figure 3 shows this for the case of light emitted from the fibres 4.1 and 5.1.

Turning now to Figure 4, the transmitter represented by what is shown in Figures 1 to 3 is indicated by reference T1. The beam which this emits, from a selected one of the fibres 1.1 to 5.5 is indicated as Beam I. The Beam I carries information, for example a speech signal, usually in PCM or FM form,and for this purpose the output of the transmitter 1 is modulated by a baseband input. The baseband information is fed to whichever one of the lasers or other optical emitters is functioning at a given time. Beam I is detected by a receiver R1. Receiver R1, like the transmitter T1, is fixed, and comprises an optical system, for example in the form of a lens or lenses, mirror or mirrors, for focussing the incoming beam.

A detector is provided at the focal plane of the receiver R1. The detector is of a type which can detect the location on its surface where the incoming radiation strikes. One such detector is available

from Setek Laboratories AB, P.O. Box 261, S-43325, Partille, Sweden, and another such is available from United Detector Technology, 12525 Chadron Avenue, Hawthorne, CA-90250, U.S.A. The location on the detector surface where the beam strikes is a measure of the angle at which the beam is received by the receiver, both as to its elevation and its azimuth. The signal from the detector is separated into its two component parts, namely baseband information, which can then be processed conventionally, and position information, i.e. information as to the point on the surface where the beam struck the detector and hence the angle at which the beam was received by the receiver.

This position information is then fed to a signal conditioning unit. Here it can be treated in one of a number of ways. In one method, illustrated in Figure 5 the position information signal, which consists of two elevation currents i_{e2} and two azimuth currents i_{a1} and $i_{a}2$ is first amplified by four transimpedance amplifiers A1 to A4 which convert the currents to voltages. These voltages are then sampled 100 times per second, converted from analog to digital form and the resulting pulses are stretched in duration from an initial value of typically 0.2 to 0.3 microseconds to say, 500 microseconds, in pulse stretchers P1 to P4.

The resulting output voltages V_{e1}, V_{e2}, V_{a1} and

V_{a2} are fed in pairs to two difference, sum and quotient circuits one of which, C1 produces outputs $(V_{e1} - V_{e2})/(V_{e1} + V_{e2})$ and $V_s = Ve_1 + V_{e2}$, and the other of which, C2, produces an output $V_a =$ $(V_{a1} - V_{a2})/(Va_1 + Va_2)$ and an output $V_s = V_{a1} + V_{a2}$ which should be the same as the output V_s produced by the circuit C1. V_e is the elevation operator and represents the elevation of the beam detected by receiver R1, and V_a is the azimuth operator and represents the azimith of the beam. The output V_s contains the baseband information.

The outputs V_e and V_a form two pulse trains in parallel, one representing elevation and the other representing azimuth. These two trains are then merged, and the resulting pulse train is formatted and sent serially to a transmitter T2 at a rate of up to 10 pulses per sample. This then emits a signal which can be understood as being an error signal, i.e. a signal which contains information as to the deviation of the angle of reception of Beam I at receiver R1 from the desired incidence. On the basis of pulses 500 microseconds in width with a gap of 500 microseconds between pulses, and 10 pulses per sample, the error signal, denoted as Beam II can be emitted at a rate of one pulse every millisecond, i.e. a thousand Hz. Because this is such a very narrow band signal it is possible for Beam II to be quite highly divergent,

since a high gain, [illegible] receiver can be used [illegible] detection. [illegible] is thus insensitive to the [illegible] atmospheric effects which necessitate precise alignment in the case of Beam I.

As mentioned above, other signal processing methods can be used in the signal conditioning unit. For example, the position information may be represented as a frequency, with a given number of bands representing elevation and a given number of bands representing azimuth. Thus, in the case of the array shown in Figure 2 ten bands can be used, five for elevation and five for azimuth, and two out of a possible ten frequencies are then transmitted, one to give the elevation and one to give the azimuth.

Beam II is detected by a receiver R2 which is then fed to a decode-encoder which decodes the signal received and converts it into a signal appropriate for use by a steering control circuit which controls the transmitter T1. The decode-encode amd the steering control may use conventional digital techniques based for example on TTL integrated circuits. The steering control circuit is operative to select which of the lasers or other light emitters of the transmitter is operative at any given moment. If, for example, the receiver R1 detects that Beam I is striking it at an angle indicative of the beam having strayed above the correct elevation the steering control circuit will

select the laser connected to a fibre in a higher row than the fibre at present in use.

The technique described takes advantage of the slowness with which significant variations in atmospheric beam bending occur, the frequency of such variations being less than 100 Hz.

The system as a whole operates as a closed loop servo mechanism with error trends being detected in advance of their becoming detrimental.

In the embodiment of Figure 6, the receiver R1 detects Beam I but does not detect the angle at which is strikes. Transmitter T2 transmits to reciver R2 a Beam II which is independent Beam I and which is a narrow frequency bandwith signal, for example a pilot tone of 10kHz. As is the case of Beam II in Figure 4, the beam can be quite highly divergent. As in Figure 4 this receiver can have a high selectivity and a very high gain. Receiver R2 detects Beam II and detects the angle at which is strikes. Because T1 and R2 are in the same vicinity as one another, and R1 and T2 are in the same vicinity as one another, the angle detected represents the angle at which beam I must in fact have struck R1. For example, if atmospheric conditions are such as to cause Beam I to be deflected upwardly by a given amount they must be such as to cause Beam II to be deflected downwardly by the same amount. Accordingly, it is possible to derive from R2 an error

signal which can then be used to control which emitter of T1 is activated.

In both the arrangement of Figure 4 and the arrangement of Figure 6, T1 and R2 can be combined, as can T2 and R1. Figure 7 shows an example of how this can be done for the arrangement of Figure 6.

A fibre output matrix F of the type shown in Figures 1 and 2 directs a beam of light to be transmitted at one face of a beam splitter BS1, from where it passes via a lens L1 to form Beam I. The incoming pilot tone from transmitter T2 also passes through lens L1, though in the opposite direction, and passes via the beam splitter BS1 to a spot position detector D.

In the combined receiver R1 and transmitter T2, the incoming Beam I passes through a lens L2 and a beam splitter BS2 to a photodiode PD. The pilot tone modulates the light output of a light source LS from which originates beam II. LS is a light emitting diode (LED), a laserdiode (LD) or any other source of modulatable light (SML). To ensure that beam II is quite highly divergent LS must have a relatively large surface area, in comparison with the cross-section of each individual fibre of the F.O matrix of T1. Alternatively, symbol LS can stand for the free end of an optical fibre "pigtailed" to an LED, or LD or any other SML. Beam combining by means other than the

beam splitters BS1 and BS2, for example optical fibre couplers can also be used.

CLAIMS

1. An optical transmission arrangement comprising a transmitter located at a first location and having a plurality of optical emitters which are selectively activatable, the emitters so arranged that light from each emitter leaves the transmitter at a different angle; receiver means for receiving the light from the transmitter and detecting the angle at which it arrives; and means for selectively activating a given emitter in dependence on the angle detected by the receiver.

2. An arrangement as claimed in Claim 1, wherein the said receiver means comprises a receiver at a second location different from the first location, which both receives light from the transmitter and detects the angle at which it arrives.

3. An arrangement as claimed in Claim 2, wherein the means for selectively activating a given emitter comprises a second transmitter at or adjacent the said second location and a second receiver at or adjacent the said first location, the second transmitter being arranged to transmit to the second

receiver an error signal indicative of the angle detected by the first receiver.

4. An arrangement as claimed in Claim 1, wherein the said receiver means comprises a first receiver at a second location different from the first location, which receives light from the transmitter, and a second receiver at or adjacent the said first location arranged to receive an error signal from a second transmitter at or adjacent the said second location, the second receiver being arranged to detect the angle at which the error signal arrives, which angle is indicative of the angle at which light is received by the first receiver.

5. An arrangement according to claim 3 or 4, wherein the error signal is narrow frequency band signal.

6. An arrangement according to any one of Claims 3 to 5, wherein the error signal comprises a component representing elevational error and a component representing axzimuthal error.

7. An arrangement according to Claim 6, wherein the two components are transmitted in series.

8. An arrangement according to Claim [illegible], wherein each component is in the form of frequency information.

9. An arrangement according to any preceding claim, wherein the transmitter at the first location comprises a fixed optical system and a plurality of optical emitters spaced from one another and selectively and individually activatable, the disposition of the emitters with respect to the fixed optical system being such that light from each emitter leaves the transmitter at a different angle.

10. An arrangement according to Claim 9, wherein the emitters are optical fibres the output ends ofwhich are disposed in an array.

11. An optical transmitter having a fixed optical system and a plurality of optical emitters spaced from one another and selectively and individually activatable, the dispositon of the emitters with respect to the fixed optical system being such that light from each emitter leaves the transmitter at a different angle, the emitters being optical fibres the output ends of which are disposed in an array.

Published 1990 at The Patent Office, State House, 66/71 High Holborn, London WC1R 4TP. Further copies may be obtained from The Patent Office.
Sales Branch, St Mary Cray, Orpington, Kent BR5 3RD. Printed by Multiplex techniques ltd, St Mary Cray, Kent, Con. 1/87